Effects of silviculture on soil and water quality in southwestern China.

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ABSTRACT

In hopes of better understanding the relationship between silviculture and water and soil quality, field studies were conducted within three managed forest types in southwestern China. Relationships between forest type, forest age, and percent slope with soil (soil N-P-K and soil moisture) and water quality [dissolved oxygen (DO), electrical conductivity, total suspended solids (TSS), pH, and temperature] parameters, were all examined. Within the soil, average nitrogen, phosphorus and potassium relative amounts (N-P-K) showed Chinese Fir to be statistically different (N-P-K=5.80) than Eucalyptus and Mason Pine (p=0.0035). Eucalyptus forests had the highest rates of fertility (N-P-K=6.79), though this could be due, in part, to fertilization efforts applied within Eucalyptus forests in the study area. Average soil moisture indicated Eucalyptus to be statistically different than both Chinese Fir and Mason Pine (p=0.0082), with a moderate decline with increasing soil depth. Additionally, water quality results indicated a positive significant relationship (p<0.05) between three of four water quality parameters (total suspended solids, electrical conductivity, and pH) and slope steepness. The results indicate Eucalyptus forests and stands with higher slope gradients will require greater management efforts to ensure soil and water quality suffer minimal further damage.

BACKGROUND

Over the years the Eucalyptus commercial forestry programs in Guangxi, China have been experiencing economic growth. In 2001 there were approximately 350,000 ha of eucalypt plantations in the Guangxi province (UNDP 2006). By the end of 2010, there were over 1.5 M ha of eucalypt plantations in Guangxi (ITTO 2011, Pei 2012) and in 2011, over 150,000 ha of new eucalyptus plantations were established in the province (IWMG 2012). With the increased demand for eucalyptus products, China's plywood production grew rapidly over the past 15 years from around 9 Mm^3 yr^{-1} in the mid 1990s to over 55 M m^3 yr^{-1} by 2011 yr by 2011 (R.J. Arnold et al., 2013). Eucalyptus expansion is of utmost concern to the region because Eucalyptus is perceived to have negative impacts on the landscape due to high moisture demand and decrease of soil quality.

Figure 1. Map of study location (Liuzhou) in Guangxi, China

OBJECTIVE AND HYPOTHESES

(1) To evaluate the affects of silviculture programs on soil and water quality.

(2) We believed stand age for Eucalyptus would impact the fertility and moisture of the local soil and that percent slope would decrease water quality of nearby water sources.

METHODS

Soil and Water Quality

A soil pit was dug in each quadrant of each tree stand for all three-tree species: Chinese fir (*Cunninghamia lanceolata*), eucalyptus (*Eucalyptus urophylla* x *E. grandis*) and Masson pine (*Pinus massoniana*). In each soil pit, measurements were taken at depths of 0cm, 20cm, and 40cm. A Hanna Instruments soil conductivity meter was used to measure the soil temperature and electrical conductivity (EC) to the nearest 0.1oC and 0.01 mS/cm, respectively. Soil pH and nitrogen, phosphorous and potassium (N, P, K) content were measured with a soil analyzer probe. Water runoff from the forest was measured by first locating pooled or flowing water immediately adjacent to the forest and in the direction of surface flow. This sometimes was small streams or drainage ditches next to the forest. A Hanna Instruments pH/Conductivity/TDS high-range tester was used to sample water at four locations next to the forest. The water temperature (0.1oC), pH (0.01), EC (0.01 mS/cm) and total dissolved solids (0.01 ppt) were measured and recorded at each sampling point. Total dissolved oxygen was also measured and recorded with Extech ExStik II Dissolved Oxygen Meter, with a range of 0 to 200.0% (saturation mode) 0 to 20.00ppm (mg/L, concentration mode).

Statistical

Data found was then analyzed in a statistical software program and a one-way analysis of variance (ANOVAs) was run for all of the quantitative data (n=4). Relationships were then observed statistically and graphically, from which we determined significant correlations (or lack there of).

Figure 2. Soil sampling equipment.

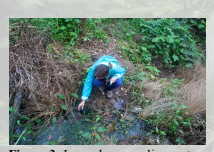

Figure 3. Jacquelyn sampling water source near Eucalyptus stands.

RESULTS

Soil Quality

Eucalyptus had the highest rates of N-P-K fertility (mean = 6.79ppm), compared to Chinese Fir (mean =5.80ppm) and Mason Pine (mean = 6.56ppm), but was not found to be statistically significant through ANOVA, although Eucalyptus's higher fertility rate could be due to fertilization during the first two years of planting. Average soil moisture indicated Eucalyptus to be statistically different (6.11%) than Chinese Fir (8.53%) and Mason Pine (7.92%).

Water Quality

Water quality results indicated a positive significant relationship (p<0.05) between three of four water quality parameters (TSS, EC, and pH) and slope steepness.

Average Soil Moisture Readings at Varying Depths in Eucalyptus Stands

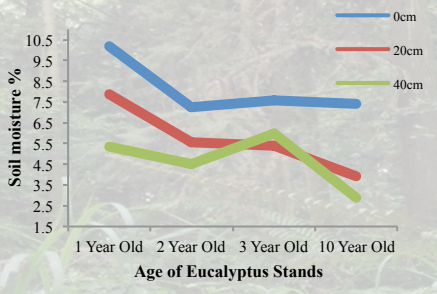

Table 1. The mean values[1] of different soil parameters

Tree Stand	n	N-P-K	Electrical conductivity mS/cm	Soil temperature (oC)	Soil pH	Soil moisture (percent)
Eucalyptus	36	6.79 A	0.0363 B	22.28 B	7.00 A	6.11 B
Mason Pine	36	6.56 A	0.0350 B	22.67 A	6.65 A	7.92 A
Chinese Fir	35	5.80 B	0.0471 A	21.68 C	5.82 B	8.53 A

Table 1. Soil parameter values by species. Note: Mean values followed by the same capital letter are not significantly different at p=0.05, Duncan's new multiple range test

CONCLUSION

The annual decrease of soil moisture in Eucalyptus stands can be attributed to the fact that the stands are being harvested and planted with the same species, not allowing the soil to replenish. Policy makers and managers should be prepared for long-term sustainable management of Eucalyptus in China. Management goals could integrate native tree species into the Eucalyptus stands to increase biodiversity, and allow soil to replenish moisture. Other goals could include sustaining surface organic matter in Eucalyptus to keep nutrients balanced as the forests are harvested and planted with the same species.

Most of the data (75%) found from the study met our original expected outcome for the relationship of forest slope to water quality, measured through four primary parameters. TSS, EC, and pH all positively correlated to forest slope; DO was found to have insignificant correlation to slope, which may be due to the small sample size. Akbarimehr et al. (2012) demonstrates a significant positive correlation between slope and runoff volume within natural forest in northern Iran. If the forest studied in Guangxi, China has a similar relationship between slope and runoff volume, this could be a likely cause for decreasing water quality with increasing slope steepness.

Because of fertilizer used on silviculture forests, steeper slopes may be likely to lose more fertilizer post-storm event than compared to a similar forest of lesser slope. Electrical conductivity, in terms of specific conductance, is typically affected by fertilizer because of the nature of the nutrients within fertilizer as salts. Total suspended solids should show a positive correlation with slope steepness due to the increase in runoff volume associated with slope steepness. As runoff volume increases due to slope steepness, larger amounts of total suspended solids will be likely to occur due to greater runoff, a source of total suspended solids (Akbarimehr et al., 2012).

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